BOREHOLE BREAKOUT ANALYSIS: RESULTS from the AND-2A Well

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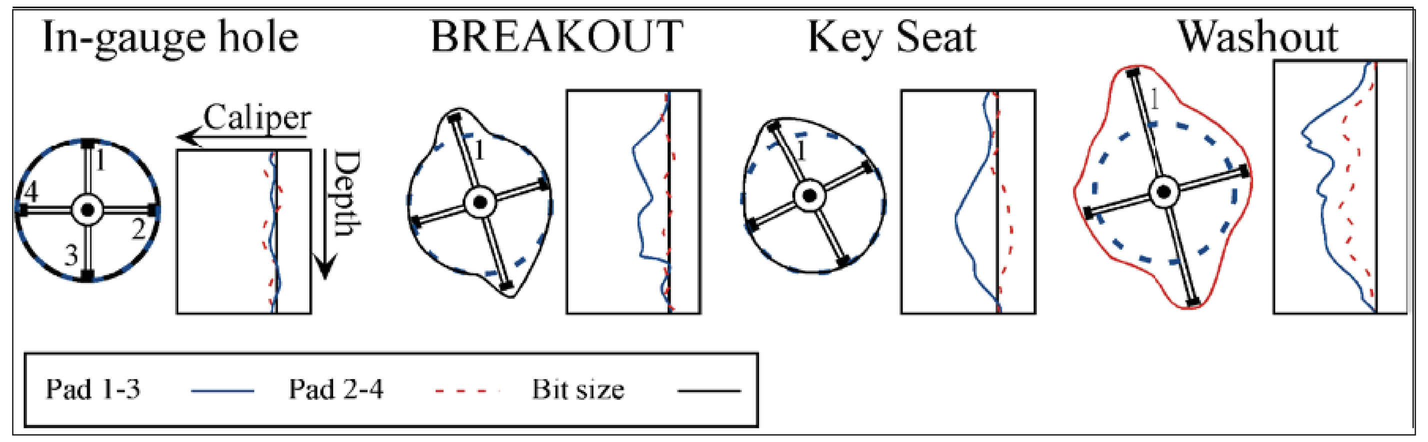
ABSTRACT

To define the present-day stress field in the upper crust and to understand the recent tectonic activity in Antarctica, a study of breakout measurements along AND-2A well was performed. The borehole breakout is an important indicator of horizontal stress orientation and occurs when the stresses around the borehole exceed that required to cause compressive failure of the borehole wall (Bell and Gough, 1979; Zoback et al., 1985, Bell, 1990). The enlargement of the wellbore is caused by the development of intersecting conjugate shear planes that cause pieces of the borehole wall to spall off. Around a vertical borehole, stress concentration is greatest in the direction of the minimum horizontal stress (Shmin), hence, the long axes of borehole breakouts are oriented approximately perpendicular to the maximum horizontal stress orientation (SHmax). The orientation of breakouts along the AND-2A well was measured using acoustic (BHTV) and mechanical (Four-Arm Caliper) tools. Borehole televiewer (BHTV) provides an acoustic "image" of the borehole wall (360 degree coverage) and gives detailed information for investigation of fractures and stress analysis. The four-arm caliper is the oldest technique for borehole breakout identification and it is included in routine dipmeter logs. A quality value has been assigned to the well results in agreement with the World Stress Map quality ranking scheme (Zoback, 1992; Heidback et al., 2010) based mainly on the number, accuracy, and length of breakout measurements. The result is presented as rose diagram of the breakout directions where the length of each peak is proportional to the frequency and the width to the variance of its gaussian curve. We have analyzed the following curves to recognize the breakout: the azimuth of Pad 1 (P1az), the drift azimuth (HAZI), the two calipers with respect to the bit size (BZ) curve and the curve relative to the deviation of the well. The AND-2A Four-Arm Caliper data cover a depth interval between 637 down to 997 mbsl, that corresponds to 360 m of logged interval. We have distinguished breakouts and some washouts only in the interval from 753 to 825 mbsl. From borehole televiewer images, we have data from 398 mbsl down to 1136 mbsl. The BHTV worked well showing a lot of interesting features such as many bedding, lamination and fractures (natural and induced) but poor breakouts. The rare breakouts have also a small size (called protobreakouts) but they are consistent with induced features. Considering the breakout result from caliper and BHTV, the AND-2A borehole is unfortunately classified as D quality. This means that to obtain a reliable active stress field of the area it is necessary to compare this result with other available data.

BOREHOLE BREAKOUT

Borehole breakouts are commonly identified using standard logging tools such as oriented four-arm caliper, borehole televiewer (BHTV), and Formation MicroScanner (FMS). The four-arm caliper provides measurement of the borehole geometry in two orthogonal directions, as well as the position of the tool with respect to the magnetic North and vertical azimuth. The BHTV collects two types of detailed acoustic data (travel time and amplitude images) of the borehole wall to gain information on the borehole diameter and acoustic impedance. The BHTV is an acoustic device which provides an image from the surface reflectivity of the borehole wall (Zemanek et al., 1970). The process of drilling a borehole may induce wellbore breakouts. Detection of these features in vertical holes allows determination of the orientation of the in situ horizontal stress. The BHTV images can be used to detect borehole breakouts, DIFs (drilling-induced fractures), and other structures that have an acoustic contrast to the borehole wall. Several different borehole geometries may be encountered during analyses. At good conditions (i.e. centralized tool, clear borehole fluid, and sufficient acoustic contrast at the borehole wall), BHTV images give a detailed shape of the borehole wall that allows separation between drilling- and stress-induced borehole elongations (key seats, washouts, borehole breakouts, DIFs).

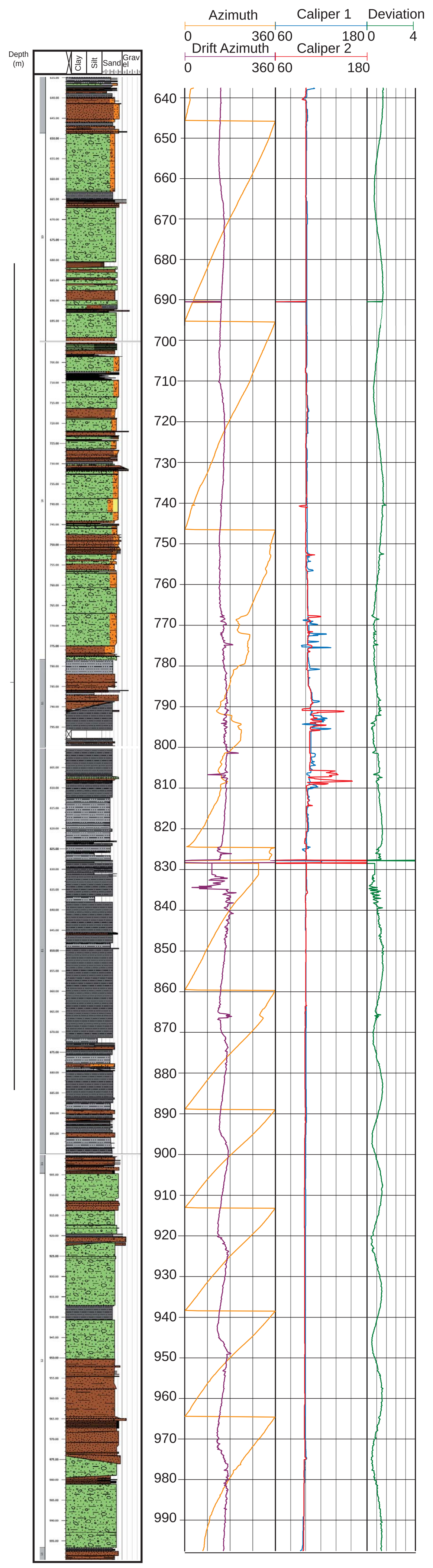


Examples of common borehole geometries and their expression in four-arm caliper logs (modified after Plumb and Hickman 1985).

AND-2A BREAKOUT ANALYSIS

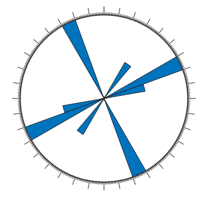
An opportunity to determine stress orientations in the Antarctic plate is provided by the SMS-Project. A method to determine the present-day stress orientation is the breakout analysis. Breakouts are one of the three types of stress-induced drillhole failures (in addition to petal-centre-line fractures and tensile fractures). To identify the breakouts along the AND-2A well the Four-Arm Caliper and Borehole Televiewer were used. Few breakouts were detected in BHTV and Four-Arm Caliper. The data from Four-Arm Caliper were not discussed in the following due to low data quality. The maximum horizontal stress indicator of the well as obtained by BHTV is N36°E+-26°.

Four-Arm Caliper

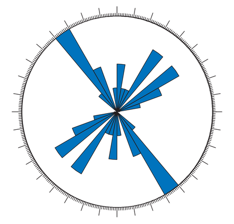


Caliper log: 637 to 997mbsl

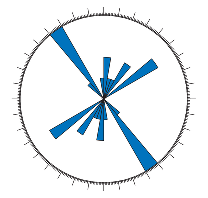
Breakout interval: 753 to 825mbsl



UNIT 10
BO=6m
SHMIN = N56E+-36°
SHMAX = N34W+-36°



AND-2A
BO=21m
SHMIN= N14E+-35°
SHMAX= N76W+-35°



UNIT 11
BO=15m
SHMIN = N8E+-32°
SHMAX = N82W+-32°

All enlargements identified in the caliper log interval are washouts.

However, data were not taken into consideration for further discussion due to low quality.

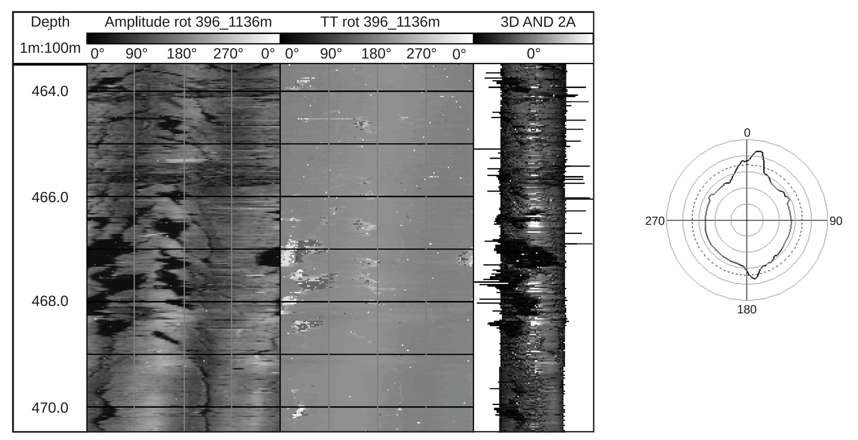
Borehole Televiewer

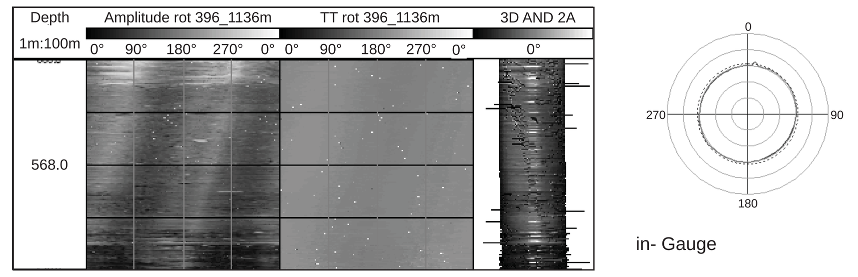
Examples of borehole breakouts. In the BHTV amplitude image (left), the borehole breakouts appear as dark, wide bands (low reflection amplitudes), 180° apart. Note also the existence of drilling-induced fractures 90° off axis form the breakouts and the natural fractures. The Travel Time (TT) images are less sensitive than the amplitude images to detect defects in the rock. Two 3D borehole images (right) were processed from amplitude data and from caliper data.

Borehole cross-sections at different depths (between 468 to 1104m). Breakouts in HQ section of the well show different Shmin orientations. Most of the breakouts in the NQ section of the borehole are elongated parallel to NW-SE direction. All of the features mentioned before can be found in the Andrill well. Apart from breakouts, in-gauge geometry is present at 568m, whereas washouts can be found e.g. at 1054m depth.

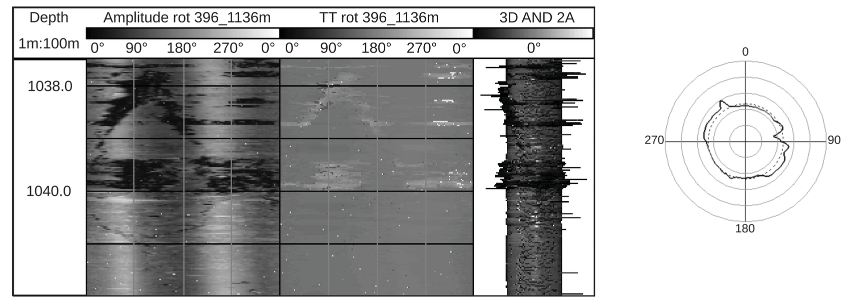
BHTV log: 398 to 1136 mbsl

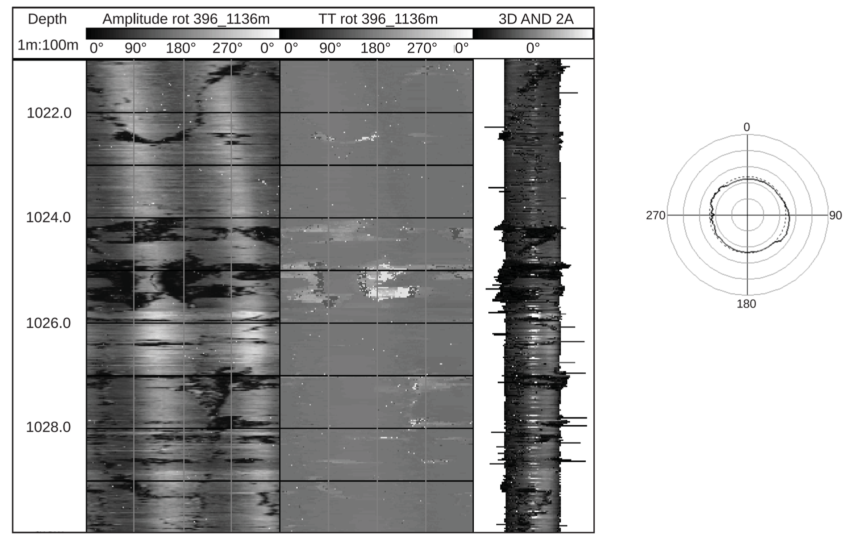
Breakout interval: 404 to 1116 mbsl

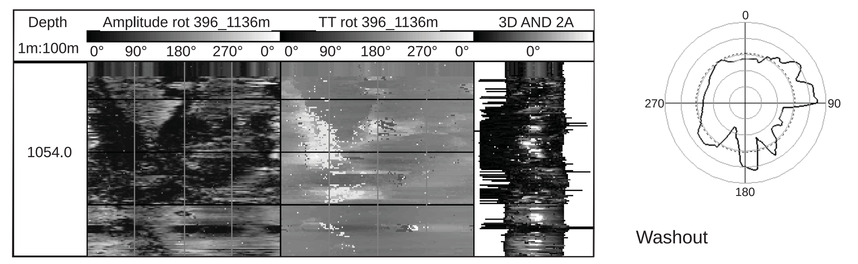




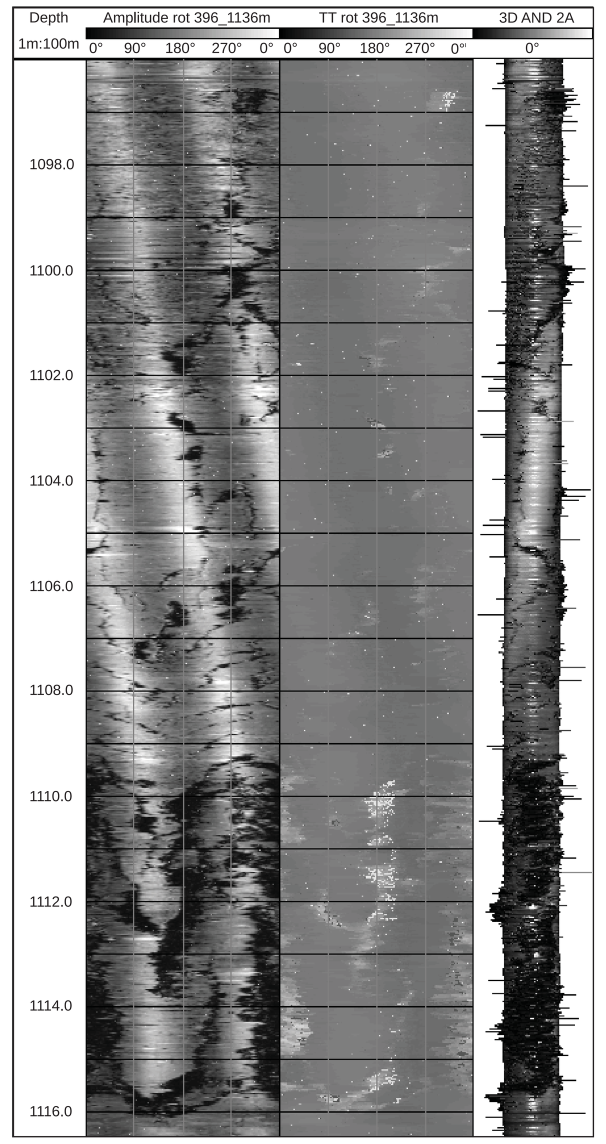
in- Gauge

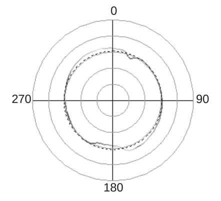




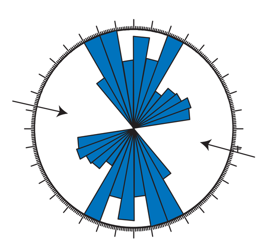


Washout



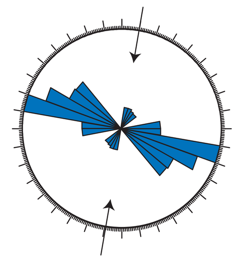


RESULTS of BHTV analysis



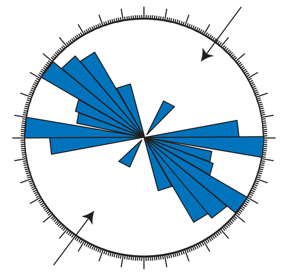
SHmax = N103°E
s.d. = 25°

HQ interval
229.4-1011.87 mbsl



SHmax = N10°E
s.d. =14°

NQ interval
1011.87-1138.54 mbsl



SHmax = N36°E
s.d. = 26°

AND-2A well

CONCLUSIONS

We have identified only few borehole breakouts along the AND/2A well by borehole televiewer analysis.
Moreover, several washout zones associated with main fractures have been recognized
The dimension of borehole breakouts is extremely small, for this reason we have denoted them as "proto-breakout".
We have split the breakout data in two sub-datasets: HQ and NQ data. The breakouts analyzed on HQ section are more scattered (s.d. =25°) and the borehole is often in-gauge.
Along the NQ section the breakouts have a consistent orientation.
Nevertheless, a low quality value has been assigned to the AND-2A drill-hole (Q=D) in agreement with the World Stress Map quality ranking scheme (Zoback, 1992; Heidback et al., 2010).

Acknowledgments

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